



BUREAU OF POINT AND NON-POINT SOURCE MANAGEMENT

CAUSE AND EFFECT SURVEY PROTOCOL

OCTOBER 2015

PROTOCOL FOR CONDUCTING CAUSE AND EFFECT SURVEYS

Cause and effect surveys are designed to investigate possible relationships between point or nonpoint sources of conventional pollutants and known or suspected instream water quality problems through the collection and analysis of biological, physical, and chemical data. This protocol was developed to establish and standardize cause and effect survey procedures and provide guidance to Department staff for conducting such surveys. The protocol should be used in conjunction with other approved Department protocols and approved methodologies.

These surveys are performed primarily to monitor the effectiveness of permitted treatment facilities but are also used to investigate reported or suspected water quality impacts for nonpoint source and other pollution sources. Since such discharges exist on a wide variety of stream and river habitats, the survey design and type of sampling gear used are dependent on stream type, site-specific conditions, and the nature of the discharge under investigation. Department staff are responsible for survey design and any modifications to survey design due to unforeseen site-specific conditions.

Survey Design

The sampling design for a cause and effect survey requires a minimum of two sampling stations. One station is placed upstream from the subject discharge(s) or impact(s) to serve as a control or reference condition and at least one station is placed in a potentially impacted zone downstream. Additional sampling stations may be necessary, either placed downstream to define zones of impact and recovery; upstream to bracket multiple discharges; or across a stream transect in wider waterbodies. For point sources, observations in the immediate vicinity of a discharge may also be appropriate.

Observations in the immediate vicinity of a discharge should include:

1. Floating solids, scum, sheen or substances that result in observed deposits in the receiving water (a small amount of foam that rapidly dissipates is typical);
2. Oil and grease in amounts that cause a film or sheen upon or discoloration of the waters of this Commonwealth or adjoining shoreline, or that exceed 15 mg/l as a daily average or 30 mg/l at any time (or lesser amounts if specified in the respective permit);
3. Substances in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life;
4. Foam or substances that produce an observed change in the color, taste, odor or turbidity of the receiving water, unless those conditions are otherwise controlled through effluent limitations or other requirements in the respective permit.

Any noted observations may or may not be violations of water quality standards and associated permit conditions. Regulatory requirements and permit conditions (25 Pa. Code § 93.6, § 92a.41(c), § 95.2(2)(i)) should be consulted.

With the exception of observations previously described, stations sampled downstream of the discharge(s) or nonpoint source should not be placed in the immediate vicinity of the discharge or nonpoint source, but instead should generally be located at least 35 meters downstream. Selecting downstream station locations is unrelated to “criteria compliance times” used to generate

NPDES permit limits. Similarly, it is not necessary to restrict the location of downstream stations to points at or downstream of the point of complete mix, as defined as the point where water quality and/or other characteristics are homogenous across a transect. If a tributary or other compromising influence is located just downstream of the discharge or source of potential impact, which would not make an upstream/downstream comparison directly applicable, Department staff may need to modify the survey design to account for differences in water quality that are not necessarily due to the discharge or source of potential impact.

Complete mix occurs rapidly in smaller streams at most flow conditions and it is typically appropriate to locate downstream stations in smaller streams at a point of complete mix. In larger streams or rivers, a plume of effluent could extend a significant distance laterally and longitudinally. If the plume does extend downstream greater than 35 meters, an indicator station may be located at or downstream of this point recognizing that any chemical, physical or biological sampling could be conducted as a composite across the transect, but effects within the plume will also be assessed if a significant portion of the receiving water is impacted. The number and placement of any discrete collections across a transect and subsequent compositing should be completed according to equal-width-increment or equal-discharge-increment methods (U.S. Geological Survey, 2006). When collecting biological samples the equal-width-increment method can be considered (i.e. effort physically distributed equally across the/a transect), but the sample should be collected in a manner such that the sample represents the waterbody across the transect and targets best available habitat according to the Department's current protocols and methodologies found on the Division of Water Quality Standards website.

If the downstream station is placed where homogenous conditions do not exist, additional downstream water quality transects and sampling stations may be necessary to characterize the effect. Any critical habitat of threatened or endangered species, as defined by the United States Fish and Wildlife Service, or any rare or endemic ecological community types, as defined by the Pennsylvania Natural Heritage Program, or any migration impediments must be identified within the defined plume or within the vicinity of the plume. The water quality and its effect on identified habitat or ecological communities and/or water quality standards shall be assessed specific to identified habitat or ecological communities.

Control or reference sampling stations may be placed at any point upstream from the discharge or source where there is no potential impact from the discharge at any river flow condition. In a low-gradient situation such as a pool, it may be most appropriate to locate the reference station far enough upstream from the discharge to preclude possible effects from pooling effluent during low river flow conditions. If there is an intake structure present, it may be most appropriate to locate the reference station upstream from the intake structure to preclude possible effects from recirculating effluent during low river flow conditions.

In some instances, if upstream conditions do not adequately represent control or reference conditions, it may be necessary to sample a separate waterbody for reference purposes. Ideally, this reference station would be selected within the same watershed or if no available reference station is found, an appropriate station should be located in an adjacent watershed. Water quality impacts to impounded waters present at least the compounding effect the impoundment itself has on water quality and water quality indicators and may prevent traditional upstream/downstream survey designs from detecting changes in water quality due to impacts other than the impoundment. To reduce or eliminate compounding sources of variability, physical habitat conditions should be as similar as possible, for each segment or separate waterbody selected for sampling. The following data will be collected at all sampling stations: benthic macroinvertebrates,

habitat assessment, water chemistry, channel cross-section and stream flow (as needed), discrete water quality transects, bacteria (as needed), and fish (as needed).

BIOLOGICAL COLLECTION METHODS

Benthic Macroinvertebrates (required)

For wadeable freestone streams and limestone-influenced streams, benthic macroinvertebrate samples are collected utilizing methods detailed in the Department's Standardized Biological Field Collection and Laboratory Methods (Pa DEP, 2013) and the Department's Instream Comprehensive Evaluations Protocol (Pa DEP, 2013a) . Cause & effect surveys on true limestone streams, as defined by Department criteria, should follow established PA DEP sampling methods and procedures for those waterways (Pa DEP, 2009). Sampling protocols include semi-quantitative, qualitative, and quantitative methods with the method to be employed being determined by the survey data needs. In most instances, semi-quantitative sampling methods are preferred and will meet most data requirements. Other optional sampling methods include qualitative and quantitative. Qualitative methods may be used in place of, or in conjunction with semi-quantitative sampling when the survey requires a more immediate result or the targeted surface water is not characteristic of surface waters used to develop a particular methodology or index.

Sampling stations consist of a control or background station placed upstream from the discharge(s) and at least one affected or impacted station downstream from the discharge(s) in the best available riffle and run habitat. When using semi-quantitative methods on freestone and limestone-influenced streams, 6 kicks from each station are composited into a single sample while working progressively upstream from the first collection "kick" site. The six kicks should be distributed over a 100-meter stream reach at each site, unless changes in land use, habitat, tributaries, chemistry or other conditions restrict the length of the sample area. Sampling equipment consists of a 0.3 m wide, 500 μ mesh D-frame kick net, and sample effort is for approximately 60 seconds per kick in a one square meter area. On true limestone streams, two kicks with an 800-900 μ mesh D-frame net should be used for cause & effect surveys. When multiple discharges are present, sampling stations are placed between discharges to characterize the effect of each input. Physical variables of all sample stations should be matched as closely as possible between background and impacted stations to minimize or eliminate the effects of compounding variables. Sample points are placed to obtain a representative benthic sample and to avoid over sampling of clustered populations.

The Department developed an index of biotic integrity (IBI) for benthic macroinvertebrate communities collected via approved semi-quantitative protocols in Pennsylvania's wadeable, freestone, riffle-run streams (Pa DEP, 2013b). Through direct quantification of biological attributes along a gradient of ecosystem conditions, this IBI measures the extent to which anthropogenic activities compromise a stream's ability to support healthy aquatic communities (Davis and Simon 1995), and can be used to compare control or reference conditions versus impacted conditions. The Department's latest approved IBI describes precision estimates for temporal variability (...whether a site's biological condition has improved or degraded over time) and intersite variability (...whether a site's biological condition is improved or degraded when compared to a nearby site). Samples collected for cause and effect surveys should be collected on the same day to eliminate the need to consider temporal variability. Intrasite variability, as determined by the IBI for benthic macroinvertebrates applies to samples collected from a single site/station (within 100 meters). Cause and effect survey upstream and downstream stations are collected from separate sites

and therefore an intersite precision estimate was developed and should be applied to compare upstream, downstream and recovery zone sites/stations. Cause and effect upstream or control versus downstream or recovery stations collected using the latest approved semi-quantitative protocols for wadeable, freestone, riffle-run streams with IBI scores greater than the intersite precision estimate will be considered impacted. The appropriate intersite precision estimate is determined by the Department's Division of Water Quality Standards, Assessment Section. Follow-up surveys may be conducted when small IBI score differences are found between control and impact sites, to confirm, or re-evaluate initial cause and effect survey results.

Fish (optional)

For most cause and effect surveys, a semi-quantitative method should be considered for wadeable streams. The objective is to acquire a representative sample of the fish population by sampling all physical stream habitats in relative proportion to their availability. The collected sample will contain most of the species in the stream at the time of sampling in numbers proportional to their actual abundances. Sampling is conducted over a representative reach of stream 10x the average wetted stream width with a 100-meter minimum and 400-meter maximum stream reach. Site length can be increased as necessary to cover all habitats (pools, riffles, runs, and cascades). Warm water streams may require additional effort due primarily to the higher number of species and individuals present. Gear and crew could range from a single backpack electrofishing crew with a minimum of 3 members to as many as three towboat electrofishing crews with a minimum of 4 crew members per towboat. Gear and crew should be adequate to acquire a representative sample. When possible, the fish are identified in the field and released. Voucher specimens and specimens which cannot be field identified are preserved in a 10% formalin solution for laboratory identification. A fish health evaluation should also be considered.

In some cases, the cause and effect assessment may allow for a less rigorous qualitative fish sampling to demonstrate the presence or absence of discharge impacts. For small or large wadeable streams, sampling is conducted over a representative 100-meter minimum reach of stream. Sampling of the reach is continued until no new species of fish are found. When possible, the fish are identified in the field and released. Voucher specimens and specimens which cannot be field identified are preserved in a 10% formalin solution for laboratory identification. A fish health evaluation should also be considered.

If fish kills are a component of a C & E survey investigation, quantitative methods would be required in cases where economic damages may need to be calculated resulting from incidents causing fish kills. In these instances, in order to support fish/aquatic life valuation-based penalties, the required fish/aquatic life data should be collected in a manner consistent with The American Fisheries Society (2003) or Pennsylvania Fish and Boat Commission (PFBC) fish kill survey procedures. In many cases, it may be more practical to coordinate field sampling activities with the regional PFBC Fisheries Management staff.

Bacteria (optional)

Because of the survey and cost complexities imposed by bacterial sampling (sample frequency and short holding times), bacteria sample collection is an optional consideration limited to when sanitary impacts from discharges are suspected. Samples for bacteriological analysis are collected to define the sanitary significance of point and nonpoint sources and assess the use attainment status of stream segments for potable water supply and recreational uses. At a minimum, a total of 5 samples are to be collected from each sampling project using a 125 ml sterile bottle. The samples must be collected on five different days, during a 30-day period, from May 1 to

September 30 to assess recreational use attainment. This supports the calculation of a geometric mean comparable to criteria specified in Chapter 93. For assessment of the potable water supply use, multiple samples per month can be collected throughout the year to generate monthly average values for comparison to applicable criteria. The samples are collected using methods outlined in the Department's Field Collection and Laboratory Methods (PaDEP 2013) and returned to the DEP laboratory where analysis is conducted following Standard Methods.

HABITAT COLLECTION METHODS

Habitat Assessment (required)

A habitat assessment is conducted on a measured 100-meter reach of stream at a minimum for wadeable surface waters. The habitat assessment process involves rating twelve parameters as optimal, suboptimal, marginal, or poor by using a numeric value (ranging from 20-0), based on the criteria included in the Riffle/Run Habitat Assessment protocol. The Habitat Assessment protocol (Plafkin et al, 1989) and field data sheets are presented in the Department's Methods appendices. The twelve habitat assessment parameters used for Riffle/Run dominated streams are: instream fish cover, epifaunal substrate, embeddedness, velocity/depth regime, channel alteration, sediment deposition, riffle frequency, channel flow status, conditions of banks, bank vegetative protection, grazing or other disruptive pressures, and riparian vegetative zone widths.

PHYSICAL – CHEMICAL COLLECTION METHODS

Detailed field observations on land use and potential sources of pollution are recorded on field data collection forms or in field books. Dissolved oxygen, pH, specific conductance, and temperature are measured in the field using hand-held meters calibrated according to manufacturer specifications and the latest approved Department protocols.

Water Chemistry Sample Collection (required)

Water samples for laboratory analyses are collected in 125, 500 and/or 1000 ml plastic bottles and any specialized containers specified by the selected standard analysis codes (SACs) with appropriate fixatives added in the field in accordance with the Department's Bureau of Laboratory's (BOLs) Supplies and Collector Information guidance found on BOLs website and the Quality Assurance Project Plan for this survey protocol.

One-time grab samples are collected, at a minimum, from a control or background station upstream from the discharge, from the discharge, and from at least one downstream affected or impacted station when evaluating point source discharges. For nonpoint discharges, grab samples are collected upstream of the impacted segment and from within the impacted segment. Bacteriological samples should be collected from each station to help better characterize point sources and, when necessary, nonpoint sources.

Standard Analysis Codes (SACs) are lists of chemical parameter analyses required to confirm specific suspected causes of impacts downstream from discharges. Water samples should be analyzed for conventional pollutants using one of the SACs for sewage or industrial wastes that are presented on BOLs website.

Water samples will be collected according to the latest version of the Department's Surface Water Collection Protocol (PaDEP 2013c).

Stream Discharge and Cross-Section (optional)

Stream discharge and/or bankfull channel cross-section are measured as needed according to the latest version of the Department's Stream Flow Measurement Protocol. At least one discharge and bankfull channel cross-section measurement is made at each sampling station.

REFERENCES

- American Fisheries Society. 2003. Investigations and Monetary Values of Fish and Freshwater Mussel Kills. (ISBN 1-888569-48-4)
(Authors: RI Southwick & AJ Loftus)
- Davis, W.S. and T.P. Simon. 1995. Introduction to Biological assessment and criteria: tools for water resource planning and decision making, W.S. Davis and T.P. Simon, eds. (pp. 3 – 6). CRC Press, Boca Raton.
- Department of Environmental Protection. 2013. Standardized Biological Field Collection and Laboratory Methods.
http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/2013_assessment_methodology/1407203
- _____. a. Instream Comprehensive Evaluation Surveys.
http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/2009_assessment_methodology/666876
- _____. b. An Index of Biotic Integrity for Benthic Macroinvertebrate Communities in Pennsylvania's Wadeable, Freestone, Riffle-Run Streams.
http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/2009_assessment_methodology/666876
- _____. c. Surface Water Collection Protocol.
http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/2009_assessment_methodology/666876
- Department of Environmental Protection. 2009. An Index of Biological Integrity for "True" Limestone Streams.
http://www.portal.state.pa.us/portal/server.pt/community/water_quality_standards/10556/2013_assessment_methodology/1407203
- Plafkin, JL, MT Barbour, KD Porter, SK Gross, & RM Hughes. 1989. Rapid Bioassessment Protocols for use in streams and rivers: Benthic Macroinvertebrates and Fish. United States Environmental Protection Agency. EPA/444/4-89-001.
- U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September 2006.